"Express Mail" mailing label number: EV329456850US

Date of Deposit: October 30, 2003

Our Case No.10541-1888

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES LETTERS PATENT

INVENTOR(S):	Vivek Jairazbhoy and Mohan Paruchuri
TITLE:	Metal Foam Heat Sink
ATTORNEY(S):	Robert K. Fergan, Esq. BRINKS HOFER GILSON & LIONE P.O. BOX 10395 CHICAGO, ILLINOIS 60610 (734) 994-6285

BACKGROUND

1. Field of the Invention

[0001] The present invention generally relates to thermal management of a semiconductor device. More specifically, the invention relates to a metal foam heat sink for thermal management of a semiconductor device.

2. Description of Related Art

[0002] In electronic applications semiconductor devices can generate significant heat performing normal operations. This heat adversely affects the performance and reliability of the devices, if not dissipated. If the heat is not dissipated, the device may overheat such that the junction temperature increases to a level causing the device to fail or function improperly. Devices and interconnects may also fail due to the effects of thermal expansion caused by the overheating. For example, stress caused by a mismatch in thermal expansion between materials can cause solder joint cracking. Therefore, it is advantageous to maximize the capability of a device to remove heat and to minimize the effects of thermal expansion.

[0003] Heat dissipation from power devices is commonly accomplished with a metal heat sink, either on the top or bottom of the device. The heat sink is typically a metal block or sheet and may include fins. Fins provide additional surface area for the dissipation of heat. Fin structures with high surface area, however, are bulky and expensive often requiring complex machining operations for fabrication.

[0004] Recently, metal foam has been used in place of fins to aid in the dissipation of heat. The porosity of the metal foam creates an enormous surface area thereby providing high heat dissipation. Metal foam may be attached to a metal block or directly to the semiconductor device. However, utilizing metal foam in

conjunction with a block heat sink requires an additional mechanical connection. The mechanical connection may be accomplished using solder or a layer of thermally conductive adhesive. This additional connection increases thermal resistance and hinders effective dissipation of the heat.

[0005] In view of the above, it is apparent that there exists a need for a heat sink that provides improved heat dissipation.

SUMMARY

[0006] In satisfying the above need, as well as overcoming the enumerated drawbacks and other limitations of the related art, the present invention provides a heat sink comprising a unitary body having both first and second portions, a porous and non-porous portion. The non-porous portion provides for the transfer and spreading of heat while the porous portion provides for heat dissipation. When implemented in a semiconductor module, including a semiconductor die and the heat sink, the non-porous portion of the heat sink is attached to the semiconductor die and configured to transfer heat to the porous portion, which dissipates the heat into the environment.

[0007] In yet another aspect of the invention, a method for manufacturing the heat sink is provided. The method includes the steps of forming a body having a first and a second portion, melting the second portion, and creating porosity in the second portion. The heat sink is made of a metal material, preferably a copper alloy. The alloy content of the portions may be varied such that the melting temperature of the second portion is lower than the melting temperature of the first portion. The varying melting temperature allows porosity to be created in the second portion.

This can be achieved by forcing gas through the second portion or by inserting a material into the second portion that may be removed, by burning or chemical reaction, after the second portion has solidified.

[0008] Further objects, features and advantages of this invention will become readily apparent to persons skilled in the art after a review of the following description, with reference to the drawings and claims that are appended to and form a part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a cutaway side view of a heat dissipating system in accordance with the present invention and implemented in connection with a semiconductor module.

DETAILED DESCRIPTION

[0010] Referring now to Figure 1, a system embodying the principles of the present invention is illustrated therein and designated at 10. The system 10 generally includes a semiconductor die 12 and a heat sink 14.

[0011] A semiconductor die 12 generates heat while performing its normal operations. The die 12 is soldered to the metal vias 24. The metal vias 24 transfer the heat generated by the die 12 to the heat sink 14 at the opposite side of the printed circuit board 22. The heat sink 14 is attached to the thermal vias 24 and the printed circuit board 22 by a thermally conductive adhesive 20. However, other means of attachment including solder may be utilized.

[0012] The heat sink 14 includes a solid non-porous portion 16 and a porous portion 18. The non-porous portion 16 provides a thermal mass for heat spreading or sinking. The non-porous portion 16 also provides the ability to absorb short term

transients allowing quick transfer of the heat away from the die. The porous portion 18 of the heat sink 14 provides an extremely large surface area for dissipation of the heat into the surrounding environment. Although, the heat sink 14 is described as a porous portion 18 and a non-porous portion 16 the heat sink is a single unitary structure thereby eliminating mechanical interfaces which may increase thermal resistance.

[0013] Natural convection may be used to dissipate heat from the porous portion 18 of the heat sink 14. However, air or liquid may also be forced through the porous section 18 of the heat sink 14. The flow of the gas or liquid cooling is illustrated by arrow 28. The heat sink 14 is preferably made of copper although aluminum or other metals may be used. In addition, the pore sizes and the thickness of each portion may be manipulated based on the package size and amount of heat to be dissipated.

[0014] In addition, a method for manufacturing the heat sink is provided. The heat sink will have a unitary body including a first and second portion. The first portion can be a solid non-porous metal block, and may include a higher alloy content thereby causing the first portion to have a higher melting temperature than the second portion. The second portion may be melted at a temperature such that the first portion remains solid. A porosity is then created in the melted or second portion of the heat sink. The porosity may be created by forcing gas through the melted portion. Alternatively, a foreign material may be inserted into the melted portion. With the foreign material integrated, the second portion may be allowed to solidify creating a porous surface area of the second portion. After solidification of the second portion, the foreign material may be removed by burning, chemical

vaporization or other methods. Additional manufacturing operations may then be performed to the heat sink including milling, drilling, or similar operations.

[0015] As a person skilled in the art will readily appreciate, the above description is meant as an illustration of implementation of the principles this invention. This description is not intended to limit the scope or application of this invention in that the invention is susceptible to modification, variation and change, without departing from spirit of this invention, as defined in the following claims.